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Strategies that Promote Elementary Student STEM Engagement

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STRATEGIES THAT PROMOTE ELEMENTARY STUDENT STEM ENGAGEMENT

by

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STRATEGIES THAT PROMOTE ELEMENTARY STUDENT STEM ENGAGEMENT

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Collaboration, creativity, persistence, and critical thinking are all skills encompassed when integrating STEM into today's classrooms. Empowering students in STEM related areas is essential for students' future success in the 21st century and educators must prepare citizens for these types of creative skills (Cook & Bush, 2018). Integrating STEM disciplines through project-based learning and providing real-world situations to solve problems enhances student engagement and achievement in STEM concepts (Cook & Bush, 2018; Hall & Miro, 2016). The topic defined in this research plan focuses on instructional strategies that make STEM more meaningful to science curriculum, as well as engaging for upper elementary students. This research action utilized a qualitative approach and was conducted using a combination of student interviews, assessments, and student self-reflections, and instructor observation notes, weekly journal entries, and teacher-lesson reflections. Key findings from this study may aid educators in providing their students with effective STEM instructional strategies that align to NGSS Standards while sparking student interest and engagement in STEM related areas. This engagement and interest in STEM led to students' academic success and will hopefully lead future youth to pursue STEM related careers.

Keywords: STEM elementary education, Rural, STEM engagement, STEM instructional strategies, NGSS, Native Americans

DEDICATION

I would like to dedicate this thesis to my husband and family for always believing in me.

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CHAPTER 1: INTRODUCTION

Problem Statement

Now, more than ever, educators realize the impact STEM (Science, Technology, Engineering, and Mathematics) has on today's youth. It is critical that teachers engage students in STEM education at an early age. According to Guzey, Moore, and Harwell (2016), "Improving STEM education is described as a high priority in recent education reports because of its potential to (1) increase the number of students who pursue advanced degrees and careers in STEM fields, (2) expand the STEM capable workforce, and (3) increase STEM literacy for all students" (Guzey, Moore, & Harwell, p. 11). Exposure to STEM related concepts will provide students with the necessary skills to succeed in the 21st century. However, teachers are finding it difficult to implement STEM effectively in their classrooms due to various reasons. Reasons such as lack of time in the school day, stress to teach to standards, and inadequate knowledge or professional development on how to implement STEM in the classroom can make effective STEM teaching a daunting task for teachers.

Today, educators are asked to teach curriculum that covers a wide variety of standards that are taught rigorously throughout the course of a year. In a traditional classroom setting, standards are addressed through teacher-led lectures, student memorization of facts, and assessments that reflect whether a student is above, at, or below grade level standards. Based on how students perform these tests reflect on the educator and whether he or she is equipping students to succeed in an ever-changing world. But how does society measure success? Is success measured by providing information to students, and then having them pass grade level standardized tests through memorization of facts? Or is success measured by creating students who can actively think for themselves, analyze what they have been taught, and apply their knowledge to various world settings? A curriculum integrating STEM can aid students in developing these skills. STEM curriculum involves current events so that students can apply skills in the engineering process that will provide a more personal, meaningful learning experience (Guzey, Moore, & Harwell, 2016). In today's standardized testing society, educators find it difficult to engage, motivate, and ignite creativity in their students. What effective engagement strategies make teachers spark the fire that ignites the flame in STEM education while still addressing standards? This teacher research action focuses on what happens to student engagement when students participate in Next Generation Science Standard (NGSS) aligned STEM lessons in a rural 4th grade classroom.

Purpose and Research Questions

Providing students with engaging opportunities by integrating STEM related disciplines can develop a set of collaborative, investigative, and creative skills that students can use in all aspects of their lives. By challenging students to think creatively through STEM, they are engaged, motivated, and inspired to gain knowledge and to achieve success. The purpose of this qualitative study is to investigate and explore instructional strategies that make STEM more meaningful to science curriculum and engaging for students in the upper elementary. The question guiding this inquiry is:

1. What happens to student engagement when students participate in NGSS aligned STEM lessons in a rural 4th grade classroom?

Methods Overview

This action research study took place in a rural school district with emphasis in a fourth-grade classroom. This research design focused on 4 students with varying academic abilities. Qualitative data were collected by the fourth-grade teacher. The data collected were: student interviews, student classwork and assessments, student self-reflections, teacher journal entries, and teacher observations.

Definition of Key Terms

STEM: An approach to education that integrates science, technology, engineering, and mathematics.

Student Engagement: Students actively taking part in the learning process in a positive, productive manner.

Rural: A remote area comprised of a population of less than 50,000 people.

NGSS: An acronym standing for Next Generation Science Standards that address K-12 science concepts and science and engineering processes and principles.

Instructional Strategies: Approaches used to enhance learning in the classroom.

CHAPTER 2: LITERATURE REVIEW

Overview

According to Gutek (2011), the Greek philosopher, Socrates, believed the teacher's task is to draw ideas out of students' minds by asking them probing and challenging questions that cause them to think critically, deeply, and reflectively about their beliefs. If Socrates were walking down the halls of a college or university campus today, you might expect him to question the popular beliefs and the current academic trends held by professors and students, forcing them to examine their ideas critically. He would challenge through lectures, books, and blogs on the internet. He might appear as an auditor in an education class, examining methods, such as authentic assessment through portfolios, constructivism, and standardized tests, and asking instructors if these methods really lead to knowledge.

Providing students with engaging opportunities by integrating STEM related disciplines can develop a set of collaborative, investigative, and creative skills that students can use in all aspects of their lives. By challenging students to think creatively through STEM, they are engaged, motivated, and inspired to gain knowledge and to achieve success. This chapter summarizes STEM research relating to captivating and inspiring students, effective instructional strategies, and NGSS standards alignment.

Student Engagement through STEM

Hall and Miro (2016) note that engaging students in STEM by focusing on real-world issues and problems is essential in captivating, inspiring, and motivating students towards STEM workforce careers. In a qualitative study involving K-12 classrooms, Hall and Miro (2016) focus on the effects of project-based learning in STEM education and examine the outcomes inquiry-based instruction has on student development and learning. The methods used during this research were direct classroom observations in a variety of STEM related courses. These classroom observations were used to measure teacher instructional practices and provided insight into student engagement. Hall and Miro (2016) defined project-based learning as the following:

> Project-based learning (PBL) can be defined as a constructivist approach to learning that assists students in gaining a deeper understanding of materials through process-oriented engagement in investigation of real, meaningful problems wherein students respond to a driving question; explore the question in situated, authentic inquiry; collaboratively problem solve; are scaffolded to extend their learning ability; and create a tangible product in response to the driving question. (p. 310)

The study found that applying a Project Based Learning (PBL) framework in classrooms has been found to increase STEM learning, such as higher-level instructional feedback and questioning strategies, integration of subject areas, student discussion and self-assessment (Hall & Miro, 2016).

Furthermore, Cook and Bush (2017) conducted a qualitative study that discusses two exemplars of design thinking within the third through fifth grades that correlates science, technology, engineering, arts, and mathematics (STEAM). Design thinking framework provides students with exposure to solving real-world problems that require collaboration and critical thinking skills as they attempt to bring good to the world (Cook & Bush, 2017). Design thinking combines STEM + Art STE(A)M, which enhances motivation in students. While conducting the study, two factors came into play when real-world problems were addressed – empathy towards others and learning from failure – skills that prepare our youth socially for the future and spark motivation and passion about generating a solution to a problem. According to Cook and Bush (2017), “The Design Thinking (DT) model purposefully integrates an empathy component through which designers need to consider the needs and values of those for whom they are designing.” (p. 94) Through this process, students can connect to situations relating to the world around them and invest in passionately solving problems by empathizing with others (Cook & Bush, 2017). From these exemplars, the study concludes that a design thinking framework teaching strategy provides a learning experience through which elementary students can meaningfully and purposefully learn integrated science and mathematics content and practices while aiming to improve the lives of others (Cook & Bush, 2017, p.101).

Overall, research suggests that using Project Based Learning and Design Thinking provides students with real-world problems to solve. Additionally, by integrating an empathy piece to STEM lessons, teachers are more likely to captivate and inspire students to engage in STEM content. Both studies also conclude that these types of pedological approaches can be challenging for teachers to implement due to lack of knowledge within the area, therefore, it is important to note that professional development that promotes project-based learning practices would be beneficial for teachers (Cook & Bush, 2017; Hall & Miro, 2016).

Instructional Strategies that Effect STEM

Given the challenges that pedological approaches may create for educators incorporating STEM, this review of literature also considered research relating to effective instructional strategies that support STEM in the upper elementary classroom. Roberts and Cantu (2012) explain three significant instructional approaches that can be applied to enhance STEM education in technology education. These design-based learning strategies, the *silo*, *embedded*, and *integrated* approach, differ based upon the way STEM content is delivered through the instruction. According to Roberts and Cantu (2012) the *silo* approach uses STEM education as isolated subject areas and is characterized by a teacher-driven classroom where there is stress on "knowledge" of the subject matter. However, the downfalls to a *silo* approach are that students only see the subjects in isolation – which may discourage them from using the subjects in an integrated method. They also mention that the *silo* approach focuses on instruction being teacher-driven, with less focus being placed on hands-on learning. The *embedded* instructional strategy centers around real-world situations, and although the technology component is emphasized, the *embedded* approach promotes learning in various contexts. Yet, a negative of the approach, according to Roberts & Cantu (2012), is that "If a student cannot associate the *embedded* content to the context of the lesson, the student risks learning only portions of the lesson rather than benefiting from the lesson as a whole" (p. 113). The third approach, the *integrated* approach, teaches students the subject areas as one subject, allowing teachers to teach cross-curricular content to deepen understanding of higher-level thinking skills. The *integrated* approach allows students to apply knowledge to different content areas and combine skills from various STEM fields. With this approach, however, teachers would benefit from professional development to enhance their instruction on *integrative* approaches. Williams (2011), noted that "Teachers often struggle to instruct through integration" (as cited in Roberts & Cantu, 2012, p. 114). When teachers struggle teaching through integration of subject areas, it may be detrimental to students' understanding of the lesson (Jacobs, 1989).

Qualitative research studies by both Roehrig, Moore, Wang, and Park (2012) and NAP (National Academies Press) (2014) indicate that integration of STEM disciplines enhances learning and achievement, as well as provides STEM-related interest and identity. These studies were focused on teachers integrating STEM in the classroom to deepen student understanding of each discipline, broaden student understanding of STEM disciplines by exposure to socially and culturally relevant STEM contexts, and increase student interest in STEM areas to promote entering STEM related fields in the workforce (Roehrig, Moore, Wang, & Park, 2012). Both studies also specified that integrated STEM experiences provide opportunities for students to productively engage with one another through collaboration while using problem solving skills, and in order for STEM education to be successful, students must be able to use disciplinary knowledge from one area and apply it to multiple disciplines.

Another area of research regarding STEM integration is a meta-analysis, quantitative study conducted by Becker and Park (2011) which analyzed the effects integrative approaches have on students' academic achievement. The findings also specified that integrative approaches are more effective in the elementary grade levels, whereas college level integrative approaches seem to be less effective. With this information, Becker and Park (2011) emphasize that integration in the elementary grades may spark motivation and interest towards STEM related careers – characteristics that will benefit our nation in future years to come (Becker & Park, 2011, p.31).

The various research studies on integration of STEM disciplines demonstrates the importance integrated instructional strategies provide for student achievement and growth. The implementation of these effective strategies in the classroom will benefit student engagement and motivation towards STEM concepts. However, implementation of the integrative approaches depends on the teacher's individual instructional method and requires teachers from all STEM disciplines to work closely with one another and commit to an integrative approach.

NGSS Standards Alignment

According to Padilla and Cooper (2012), the emphasis Next Generation Science Standards (NGSS) places on engineering practices and technology will better enhance STEM implementation in the classroom and lay the foundation for the STEM content that should be taught to all students by the end of their high school academic career. According to NGSS:

> Within the Next Generation Science Standards (NGSS), there are three distinct and equally important dimensions to learning science. These dimensions are combined to form each standard – or performance expectation – and each dimension works with the other two to help students build a cohesive understanding of science over time. (www.nextgenscience.org, 2019)

However, Daily (2017) notes that there are many time constraints throughout an academic school day, therefore, limiting time to teach science. Daily (2017) suggests teachers use the Engineering Design Process (EDP) that is embedded in the NGSS Standards to create integrated thematic units that will combine content areas and promote critical thinking and problem-solving skills. The practices embedded in NGSS increase in difficulty across grade levels and according to Daily (2017):

> Grades K-2 students are asked to define a simple problem that can be solved through the development of a new tool or refinement of an existing tool, whereas, Grades 3-5 students are instructed to use prior knowledge to identify an existing problem that can be solved through the development of a new tool. (p. 138)

The EDP can be used to differentiate and challenge students, and many of the EDP challenges can be adapted to meet standards at various grade levels, making it a versatile component.

Guzey, Moore, and Harwell (2016) state the following:

> Science teachers are expected to teach intersecting concepts and core disciplinary science using scientific and engineering practices. The integration of mathematical reasoning, problem solving, and technological literacies to scientific and engineering practices are grounded in NGSS as well. Making learning of STEM subjects more relevant to students' lives and helping them to see connections between and among STEM subjects represents an integrated approach, which can increase motivation to learn science, as well as enhance conceptual understanding of science. (p. 12)

The study in this article comprised 48 science teachers, who were trained to develop and assess STEM curriculum units. Each of the units focused on students engaging in real-world related problems where they were asked to design, build, test, and re-design an artifact to apply the science and math concepts that they were learning. A STEM Integration Curriculum Assessment Tool was used to assess the curriculum units.

According to Guzey, Moore, and Harwell (2016), the STEM Integration Curriculum Assessment Tool comprised of nine areas – motivating and engaging context, engineering design, integration of science content, integration of mathematics content, instructional strategies, teamwork, communication, assessment, and organization (Guzey, Moore, & Harwell, 2016). The engineering practices that are incorporated into NGSS are also supported by this assessment tool. Guzey, Moore, and Harwell (2016) state, "Students need to explore and apply the necessary science and mathematics concepts in order to solve the engineering challenge. Furthermore, the learning goals and objectives of the unit are all tied meaningfully to the standards" (p. 21).

Summary

Having reviewed the above literature, providing students with engaging instructional opportunities by integrating STEM related disciplines can be beneficial in enhancing student learning. By implementing instructional strategies that correlate STEM lessons to NGSS standards through learning goals and objectives, educators can deepen student understanding of science concepts while challenging students to think creatively and critically through STEM. However, there is little research on what happens to the level of student engagement when students participate in NGSS aligned STEM lessons. The research project conducted is unique compared to other literature as it provides insight on how student's perceive STEM and the impact STEM has on their learning process. The research also discusses effective teaching strategies that affect student learning in STEM, as well as align to NGSS standards.

CHAPTER 3: METHODS

Overview

The purpose of this qualitative action research study is to investigate and explore instructional strategies that support NGSS Standards and engagement in STEM for upper elementary students. The question guiding this inquiry is: What happens to the level of student engagement when students participate in NGSS aligned STEM lessons in the 4th grade?

As previously indicated in the Literature Review, pedagogical approaches, such as Project-Based Learning and Design Thinking, improve student engagement and motivation towards STEM, as well as improves student achievement and success (Cook & Bush, 2017; Hall & Miro, 2016). As the researcher, I collected and analyzed data to evaluate and determine instructional strategies that support NGSS Standards and promote engagement of STEM concepts. I then used the data to identify emerging themes and trends regarding the effective STEM instructional strategies that support NGSS Standards and engage students.

Context of the Study

Niobrara Public School District is located in the community of Niobrara, Nebraska, with an approximate population of 370 citizens. According to the Nebraska Department of Education website, Niobrara Public Schools is a Class III school district located in northeast Nebraska along the scenic Niobrara and Missouri Rivers. It serves approximately 170 students over 150 square miles, with 78 percent of students receiving free and reduced lunch. The student population is reflective of the diverse cultural realm that the district serves. There are significant numbers of American Indian (Santee Sioux and Northern Ponca) students receiving their education at Niobrara Public Schools. The district was divided into a K-5, 6-8, 9-12 organizational structure beginning with the 2005-2006 school year. This allows teachers to concentrate on specific content areas with benchmark standards guiding the curriculum. Teachers are able to work with students for four years in a content area allowing for greater student success.

Participants

The participants in this study are the 4th grade students in the researcher's classroom, with an emphasis on four students. Nineteen students participated in the study. Four of these students were interviewed during the research and were chosen based upon their various academic levels, abilities, and needs. Two of the four students are on an individual education plan, one of the students is of Native American ethnicity, and one of the four students is female. For confidentiality purposes, pseudonyms were given to each of the students. Work samples, reflections, and assessment data were collected on all nineteen student participants in the 4th grade, whereas interviews were conducted with only the four students.

Data Collection

The data collected during the study comprised a combination of student interviews, student coursework, assessments, and self-reflections, and instructor observations, weekly journal entries, and teacher-lesson reflections.

Student Interviews

The data collected during the research were four interviews of the students chosen based upon various academic levels. Of the four participants, two interviewees were on an individual education plan (IEP) and receive special education services. The other two interviewees were students in the mainstream classroom. The interviews were conducted at the end of each STEM lesson within the unit to determine engagement, motivation, and understanding of science content relating to the lesson. The interviews comprised of open-ended questions relating to STEM interest and science concepts (see Appendix A).

Student Assessment and Reflections

A unit assessment on Energy and Energy Design was collected and scored at the end of the unit to measure student understanding of the concepts. During the unit, students' written work was analyzed by examining students' STEM notebooks or worksheets. Student STEM reflections were collected after STEM lessons as a self-reflection piece for students and to provide insight to student understanding of the STEM lesson taught.

Teacher Journal Entries and Reflections

During the four STEM lesson activities within the unit, I performed classroom observations focusing on student collaboration and engagement in STEM project learning. From these observations, I wrote and reflected in weekly teacher journal entries for professional growth. After STEM lessons, I documented in a reflective journal the successes and challenges of the instructional strategies implemented during the lessons. From this documentation, I made necessary changes or additions to the STEM lessons.

Data Analysis

Student interviews, written work, and self-reflections were coded and analyzed to identify connections and themes and were used as a primary data source. Teacher journal entries, observations, and lesson reflections were coded and analyzed to identify themes and excerpts that illustrate and support these themes. Teacher journal entries, observations, and lesson reflections were used as a secondary data source. Following a procedure described by Gallicano (2013), each interview question answer was read as an initial coding and open coding began on the second reading. Examples of student's words were interpreted based upon a common theme, and from those examples, properties, and open codes were generated. Open codes were examined to identify themes and patterns in the data, and from the open codes, axial coding was identified and illustrated. A selective code was then generated based upon a core variable that was identified to embrace the data.

Student written work and the unit assessment were evaluated to measure student learning and the effect STEM lessons had on the learning of physical science content. Percentage scores on the unit assessment determined learning growth of the content and student reflections were used to provide insight to student understanding of the STEM lesson taught.

The Energy and Energy Design Unit expanded over a six-week period during the 3rd and 4th quarters of the school year. During the Energy and Energy Design Unit of study, I wrote weekly journal entries on the STEM lessons being taught that week or the science content that I addressed to provide background knowledge for the upcoming STEM lessons I planned on teaching. I also answered lesson self-reflection questions after each STEM lesson to use as a guide for upcoming lessons and effective teaching strategies. Again, a Grounded Theory Approach was used to code the journal entries and lesson self-reflections. I categorized the open codes I generated in my journal entries and self-reflections into like terms and found an axial code that identified that theme. From the axial codes, I distinguished a common selective code for the data.

Summary

As the researcher, I collected and analyzed student interviews, written work, and self-reflections and teacher journal entries, observations, and lesson reflections to evaluate and determine instructional strategies that support NGSS Standards and promote engagement of STEM concepts. I then used the data to identify emerging themes, connections, patterns, and trends regarding STEM instructional strategies that support NGSS Standards and engage students.

CHAPTER 4: FINDINGS

Overview

The data collection procedure took place during science class for approximately six-weeks during the 3rd and 4th quarters of the year. Science class went from 2:15 to 3:05 Monday through Thursday and from 9:00 to 9:45 on most Friday mornings where it shared scheduling time with writing. Therefore, science was not always taught on Fridays. Note that due to the extent of the science lessons, the lessons were often taught over a period of 3-5 days. Two class periods were often utilized as a ‘whole group’ approach, and two to three class periods were often utilized for the STEM lesson where students were working collaboratively in partners or groups.

A typical classroom day during science class often began with asking the students a bell ringer from the previous day’s content to engage the students and reiterate prior knowledge of the content being discussed in the day’s class period. As a way to promote movement in the classroom, I would typically have my students answer the bell ringer questions through various activities that would require them to get up out of their seats. One such teaching strategy I used and will describe is *hand up, stand up, pair up,* or as the students like to call HU-SU-PU. Students would be asked a question, put their hand in their air ready to give someone a high five (hand up), stand up and walk around while music was playing (stand up). When the music stopped, they must find a partner (pair up) to share their answer with. Students would then share with the rest of the class they and their partner’s answers to the bell ringer questions. Example bell ringer questions prior to a STEM lesson to enhance knowledge on potential and kinetic energy would be *give an example of an object that possesses potential energy, give an example of an object that* *possesses kinetic energy, as a rollercoaster goes down a track, the energy transfers to* _________ *energy* and *as a moving object slows down, its* __________ *increases.* Once questions have been answered and discussed, I would draw my students' attention to the objective chart on display at the front of the classroom. To set the tone and purpose for the lesson, I would have the students read the objective aloud to serve as a guideline and basic understanding of what they were going to be learning today. Each science lesson's objectives are based on our district's local science curriculum and are comprised of components that are broken down to meet the unit's outcome. The Energy and Energy Design Unit's outcome is *students will classify types of energies, convert energies from one form to another, and evaluate the effect on the environment due to human use of natural resources as energy sources.* An example objective for the Energy and Energy Design Unit described would be *Students will explain relating the speed of an object to the energy of an object and differentiate between potential and kinetic energy.* The objectives for each unit are based on the Nebraska Science Standards, which also correlate with the NGSS. The example objective stated above relates with Nebraska Science Standard *SC.4.4.2.A* and the NGSS Standard *4-PS 3-1 Use evidence to construct an explanation relating the speed of an object to the energy of an object* (www.education.ne.gov/science;www.nextgenscience.org).

On a typical day, I often have my students as a whole group engage in various video clips, websites with phenomena related to the lesson, reading passages, and note-taking in their science notebooks. I prefer to teach the lesson using a 'whole-group' approach rather than students acquiring the knowledge independently via a technology source (iPad, computer, etc.). I feel that students gain a better understanding of the science content using a ‘whole-group’ approach because they are given the opportunity to discuss aloud their thoughts, ideas, and perhaps misconceptions on the science content being taught. Once I have taught the science concepts and vocabulary, I provide students the opportunity to discuss with partners or groups (based on desk arrangements) the exit ticket question as a way to informally assess their knowledge of what has been taught. Various methods were used for exit ticket questions, such as individual whiteboards or post-it notes. Once students have provided understanding of the science concepts and vocabulary, I would introduce the STEM lesson that aligns to the objective being taught.

For every STEM lesson introduced, I would make a real-world connection where the students were asked to solve a real-life situation using problem-solving skills. The Engineering Design Process was referred to during every STEM lesson as a guideline for the STEM procedure. A classroom bulletin board was used as a visual for the students to remember the steps of the Engineering Design Process – 1) Ask 2) Imagine 3) Plan 4) Create 5) Improve 6) Present. Students also set up STEM notebooks using the steps of the Engineering Design Process during the STEM lesson. In these notebooks, students filled out various portions of the notebooks together as a class, such as answering questions about the lesson. Then they would be given the opportunity to fill out portions of the notebooks with their partners or group members, such as brainstorming their ideas, initial sketches, and taking notes on what’s working and what’s failing. If students were asked to research before designing and creating their prototype, they often used the computer lab or iPads to conduct their research and take notes in their STEM notebooks. After completing the STEM lessons, students would then elaborate on what they learned by answering self-reflection questions such as *What did you learn from this experience?*

Would you want to do this again? How well did you work with your group? What were some creative risks that you took? Why is brainstorming with others important? What are the advantages and disadvantages of wave energy? How is energy transformed from one form of energy to another? What is the law of conservation of energy? By answering self-reflection questions on the STEM lesson process as well as the science concepts taught, I understood how the STEM lesson impacted the students' learning of the science content.

Table 1

STEM lessons performed in the Energy and Energy Design Unit

STEM Lesson:	**NGSS Standard:**	**Real-World Challenge Encompassed in Lesson:**
Roller Coaster Force and Motion STEM Challenge	4-PS3-2 Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.	Students were asked by a local theme park to develop a new roller coaster.
	4-PS3-4 Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.	
Chain Reaction Machine	4-PS3-2 Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.	Students were asked to create a chain reaction machine to make a task in their life easier.
	4-PS3-3 Ask questions and predict outcomes about the changes in energy that occur when objects collide.	
	4-PS3-4 Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.	
Designing Solar Plane, Cars, Boats, and Vehicles	4-ESS3-1 Obtain and combine information to describe that energy and fuels are derived from	Students will work together in a design team to research and create a type of solar

	natural resources and their uses affect the environment.	vehicle of their choice (plane, car, boat, or rover).
Design a System to Harness Wave Energy	4-ESS3-1 Obtain and combine information to describe that energy and fuels are derived from natural resources and their uses affect the environment. (nextgenscience.org)	Students imagine they live on the California coast and work for the state's energy department. They are asked to build and demonstrate a model of how wave (tidal) energy could be used as an alternative source of energy.

Table 1 identifies the four STEM lessons performed during the unit, the aligned standards, and the real-world challenge that is encompasses within each lesson.

The four STEM lessons performed during the Energy and Energy Design Unit served as focal points to determine findings encompassing the research question – What happens to student engagement when students participate in NGSS aligned STEM lessons in a rural 4th grade classroom? From the data collected during the unit, I was able to provide three assertions that answer the aspects of the research question at hand.

STEM Fosters Student Engagement

Student interviews performed throughout the unit, student self-reflections, and teacher classroom observations support the assertion that STEM fosters student engagement in the upper elementary classroom. During each student interview, the students were eager to share their thoughts on STEM projects and how STEM both motivates and helps them learn science concepts. Students answered various questions that provided insight into their level of engagement during STEM lessons. Many of the students noted they enjoyed the hands-on learning, physical movement, and creativity that STEM lessons offered. Students also enjoyed collaborating with their peers rather than working independently. The results for interview questions supporting the assertion that STEM fosters student engagement are as follows:

Interview Question #1: Why do you find it important to participate in STEM lessons?

Three of the four students mentioned STEM lessons being enjoyable and liked the physical movement involved with STEM. Sally revealed that STEM helps her get a better grade. Ricky stated:

> Because I believe it's important to do physical activities and I believe that STEM helps kids learn what the teacher's teaching. Not just paper because that won't help kids very much and it won't make it stick in their heads. If they do physical activity, they will be able to remember what they did.

Gary mentioned the following:

> Because it gives you a challenge and it makes your brain work because if you want to be a farmer you have to know how deep your machines are digging in and how much they're taking out. It makes your creativity go free.

The open codes generated from this interview question are 1) hands-on learning and 2) physical movement.

Interview question #3: STEM lessons require students to work collaboratively together. How do you work with others to solve problems?

Many of the students mentioned discussing ideas and bringing creativity from each other together as a team are qualities of working together to solve a problem. An example is when Alan stated, "I feel like I can do way better in groups because you don't have to build everything on your own. You can bounce ideas off people to get better ideas."

Ricky expressed:

> I work well with other kids, but it's difficult but it can be better because if you have many ideas, you can put them together instead of just doing your idea. If no one else is working with you, it might be harder. If you have a bunch of people in your group, you can use other people's ideas and then you can combine ideas.

The open codes for this interview question are the following 1) wanting peer interaction for teamwork skills and 2) combining peer ideas.

Interview Question #6: What happens to your level of engagement during class when you participate in STEM lessons?

Many of the students stated they were excited to do STEM lessons. Sally mentioned, "It increases because I love doing STEM challenges."

Ricky communicated:

> It makes me more involved in it and I just like it because you can do hands-on learning. I think hands on learning is just better than doing something on a piece of paper. In order to know things for kids who want to be active, you have to get your hands dirty and do some work with your hands.

The open code pertaining to this interview question is 1) participating in STEM keeps me engaged and excited to learn.

The interviewees' statements in regard to STEM lessons indicates that they enjoy learning approaches that are hands-on, give opportunities to collaborate with their peers to discuss ideas, and provide freedom to showcase ingenuity and science concepts through STEM activities. By open coding the student interviews, the selective code that emerged from the data was - STEM lessons challenge, excite, and help students better understand concepts through student collaboration.

Table 2

Open Codes, Axial Codes, and Selective Code for Student Interviews

Open Code	Axial Code	Selective Code
I should continue STEM lessons next year because hands on learning helps students understand concepts;	Participating in hands on learning through STEM lessons excites and helps students understand concepts easier.	STEM lessons challenge, excite, and help students better understand concepts through student collaboration.
learning of content is easier to grasp; hands on learning/physical movement;		
enhanced learning of concepts; participating in STEM keeps me engaged and excited to learn.		
Redesign is beneficial in making my project work effectively; persisting through work is easier now than at the beginning of the year; don't fear failure.	STEM helps students work through challenges.	
Be a team player; wanting peer interaction for teamwork skills; combining ideas	Collaboration of ideas helps in STEM lessons.	
Science and Math are key components in STEM	Engineering and Technology are overlooked in STEM.	

Table 2 shows the axial codes and selective code based upon open codes. All other open codes, properties, and examples of student's words are displayed in the tables found in the appendices (see Appendix B).

After completing a STEM lesson on chain reactions, students filled out a 'My STEM Challenge Reflection' where students were asked several questions describing the challenge they worked on, how they incorporated science, technology, the engineering process, and mathematics, and whether they liked and would recommend the activity. All fifteen students specified that they liked and would recommend the activity. After completing self-reflections on designing a system to harness energy from ocean waves, Sally mentioned, "I learned that you can create electricity using water which is called hydroelectricity. I would like to do this again." She also noted that her and her partner worked well together and "It is important to listen to other people." Gary stated, "We learned we could create electricity from the ocean and how to make turbines and how they work." He mentioned that it was important to brainstorm with others to make the design better.

I was able to merge my journal entry findings into three open codes based on distinctive common themes that emerged from the data. The themes that arose coincide with the assertion that STEM fosters student engagement. I noticed that many of the similarities I found among each journal entry was that students enjoyed working collaboratively to discuss ideas and were engaged in the lesson when they could discuss and talk with their peers. I noted that groups were rarely off task when it came to group work and that the students worked best when they were given a real-life situation to solve a problem for. The teacher lesson reflection questions *"Were the students productively engaged? How do I know?"* also helped support the assertion. Notes and observations answering these questions after each STEM lesson were that students actively took part in group decision and were assigning each other tasks. They were verbalizing science vocabulary during the STEM process (particularly when noticing energy transfer), and students used allotted amount of time efficiently. Codes emerging from these notes, such as students' use of science terms and concepts were used appropriately, and students assigned roles and asked appropriate questions relating to the lesson during the STEM process reinforce the statement that STEM fosters student engagement in the upper elementary.

STEM Enhances Learning of Science Concepts

Student assessments and interviews, as well as teacher classroom observations assist in supporting the assertion that STEM enhances learning of science concepts in the upper elementary classroom. STEM lessons were used in the classroom to improve learning of science content by applying prior taught knowledge to increase students' understanding of concepts.

I used an end of the unit assessment as an indicator of student knowledge obtained after the Energy and Energy Design Unit of study. The unit assessment would also provide me with knowledge on how STEM can affect the learning of physical science concepts at the 4^{th} grade level. This assessment would measure student knowledge of my school district's local science curriculum outcome S.4.3: Students will classify types of energies, convert energies from one form to another, and evaluate the effect on the environment due to human use of natural resources as energy sources. Although the unit outcome and components are aligned to the Nebraska State Science Standards, they also correlate with the NGSS standards Disciplinary Core Ideas – Definition of Energy and Conservation of Energy and Energy Transfer. The specific NGSS standards that align to this outcome are: 4-PS3-1 *Use evidence to construct an explanation relating the speed of* *an object to the energy of that object*, 4-PS3-2 *Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents,* and 4-PS3-4 *Apply scientific ideas to design, test, and refine a device that converts energy from one form to another* (nextgenscience.org).

Table 3

Energy and Energy Design Unit Outcomes and Components

Energy and Energy Design		
S.4.3	**Outcome: Students will classify types of energies, convert energies from one form to another, and evaluate the effect on the environment due to human use of natural resources as energy sources.**	
	Students will ...	
	S.4.3.1	classify types of energy to include electrical, light/solar, sound, light, and heat.
	S.4.3.2	explain relating the speed of an object to the energy of an object and differentiate between potential and kinetic energy. (SC.4.4.2.A)
	S.4.3.3	predict how energy is changed but conserved when objects collide. (SC.4.4.2.C)
	S.4.3.4	design, test, and refine a device that converts energy from one form to another. (SC.4.4.2.D)
	S.4.3.5	plan and carry out fair tests in which variables are controlled and failure points are considered to identify points of improvement. (SC.4.4.2.E)
	S.4.3.6	validate examples of thermal energy transfer: conduction, convection, radiation.
	S.4.3.7	identify types of conductors and insulators.
	S.4.3.8	obtain and combine information to describe that energy and fuels are derived from natural resources and that their uses affect the environment. (SC.4.4.2.F)

Table 3 indicates the outcome and components (e.g. S.4.3.1) that address the Energy and Energy Design Unit. The Nebraska State Science Standard is specified in the parentheses (e.g. SC.4.4.2.A).

The unit assessment was comprised of various questions based on the unit's components that supported Outcome S.4.3 stated above. Three of the twenty-six questions on the assessment related to component S.4.3.1, six questions related to component S.4.3.2, two questions related to component S.4.3.3, six questions related to component S.4.3.6, five questions related to component S.4.3.7, and four questions related to component S.4.3.8. Because components S.4.3.4 and S.4.3.5 are performance-based in criteria, I assessed students' STEM designs, written reflections, and STEM assessments of learning to measure student growth on the following STEM projects: design a system to harness powerful energy from ocean waves, create a chain reaction machine, design a solar vehicle of choice, and design a low-cost themed roller coaster. All STEM designs, written reflections, and STEM assessments of learning were completed prior to the Energy and Energy Design end of unit study so that science content taught and learned from STEM lessons would transfer to the end of unit assessment.

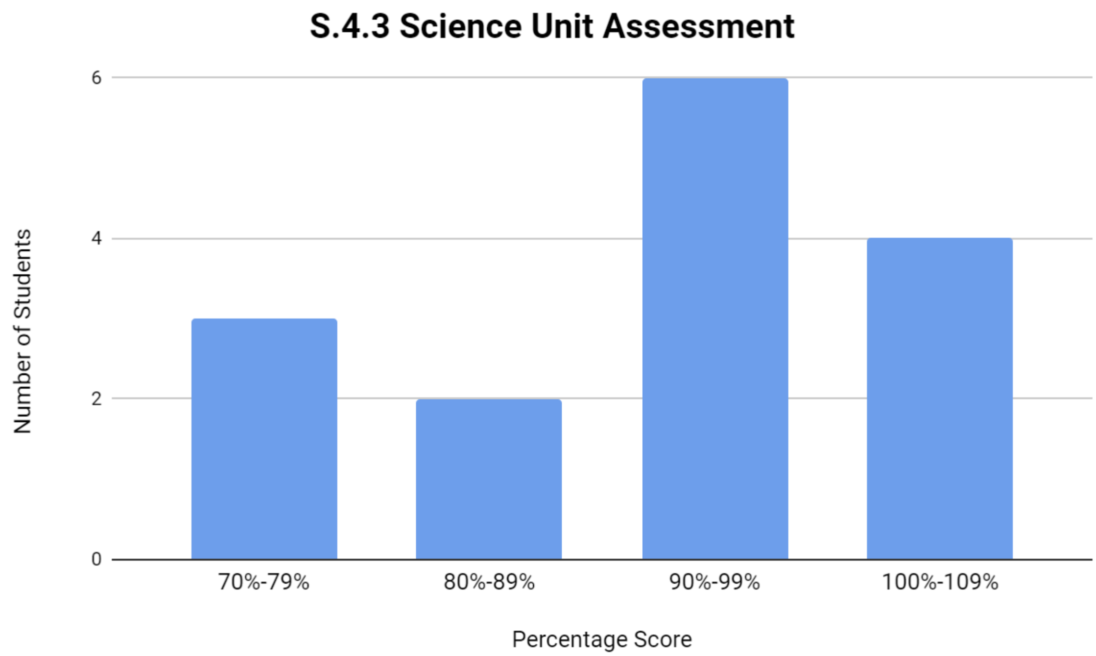

Figure 1. The bar graph indicates the percentage scores of the S.4.3 Science Unit Assessment for 15 students.

At the end of the unit, more than half the students had received a 90% or higher, which indicates those students had mastered the content deeply. Since a pre-test was not performed prior to the unit, I had no baseline indicator of students' knowledge prior to the unit. However, prior to teaching the Energy and Energy Design Unit, I used a "Dot Chart" to collect evidence of engagement, growth, and learning of energy transfer. This chart helped me as a facilitator gauge were my students were at prior to the delivery of the content of the unit. Students rated themselves on a scale from one to four (1 = ummm what?, 2 = I've heard of it. 3 = I'm okay, but may have questions, and 4 = I've got this completely!) The students then placed a sticker dot under the category that best described their knowledge of the content before the lesson. Most students had not heard of vocabulary terms, such as 'momentum' and the equation 'p=mxv' but were familiar with the term ‘energy transfer’. After students had placed the sticker dot under the heading they deemed appropriate, we discussed as a class what they considered each topic represented and what they did or did not know about each one. Although many of the students indicated they knew the term ‘energy transfer’, they could not define it correctly, which identified they did not have a strong understanding of the term.

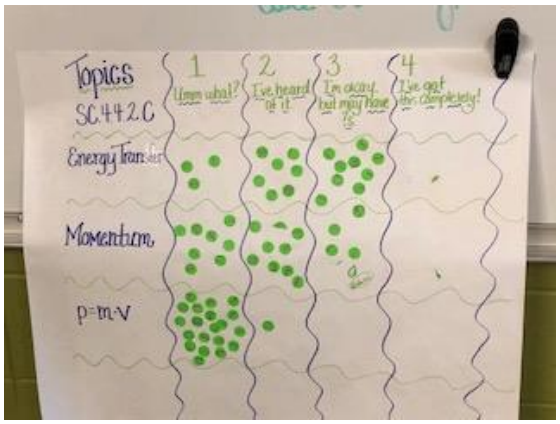

Figure 2. A dot chart used to gauge student learning. This figure illustrates the dot chart used to measure student understanding of energy transfer.

Interview questions were analyzed and coded regarding the assertion that STEM enhances student learning of science concepts. When students were asked the question, “*How does your level of understanding STEM related subjects change when participating in STEM lessons?”* many students generalized that learning of content is easier to grasp when STEM lessons are performed. Alan stated, “I understand them. I don’t like someone straight telling me something. I like the examples that STEM gives you.”

Sally referred to the STEM lesson on potential and kinetic energy when she answered, “When we are learning force and motion, I think building the rollercoasters was an easy way to understand it.”

Teacher observations and journal entries served as documentation that related knowledge deepens understanding of science concepts prior to STEM lessons. Once science concepts were taught, the content developed and extended while performing STEM lessons. I noted in teacher journals that lessons were most successful when I provided background knowledge through reading passages, internet sources, and videos that supported the science standard I was addressing. Phrases that I commonly used in my teacher journals and observations were *taught vocabulary and science content prior to lesson, gained deeper understanding of energy in motion,* and *addressing lessons to standards.*

Evidence of success when providing background knowledge through various materials was analyzed through classroom observations and notes. As STEM lessons were being performed by students, I observed and noted that students continuously were using appropriate vocabulary terms and information when asked various questions. For example, when asked how science was incorporated into the STEM chain reaction lesson, students would say phrases, such as, “We had to make a ramp for height, so our marble had enough stored energy” and “Things that have more height have more energy.” I also heard students conversing with partners saying, “The larger the marble we use, the more mass it has and will transfer more energy to our objects.”

Engineering Design Process Through STEM Provides Student-Centered Approach

As noted previously, data verified students enjoyed learning science concepts through a hands-on approach where they collaborated with their peers. Both learning methods are rooted within the Engineering Design Process. Teacher journal entries, lesson self-reflections, and student self-reflections provide evidence of the assertion that implementing the Engineering Design Process through STEM provides a student-centered approach when teaching standard aligned content.

Commonalities that arose from data within the teacher journals were centered around the Engineering Design Process (EDP) and how the STEM lessons embedded this process. Common phrases that were identified were *Engineering Design Process tasks before designing, standard SC 4.4.2.D – design, test, and refine a device that converts energy from one form to another, answering questions to enhance design, design and create solar vehicle, research, design and label.* Students were provided with background knowledge on various sources of energy, with an emphasis on renewable and nonrenewable energy sources. After learning about solar, tidal (wave), and wind energy, students utilized the EDP to design, test, and refine a device that converts energy from one form to another. Students worked in groups to design a solar vehicle (boat, car, plane, or rover) of their choice as well as a system designed to harness wave energy. Before each lesson, I reviewed the steps of the Engineering Design Process and as the STEM lesson was undergo, students referred to the EDP while completing their STEM Notebooks for each of the lessons. Focusing on the EDP while performing STEM lessons supported two NGSS 4th grade standards – 4-PS3-2 *Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents* and 4-PS3-4 *Apply scientific ideas to design, test, and refine a device that converts energy from one form to another* (www.nextgenscience.org). Placing an emphasis on the EDP during STEM lessons aided as a step-by-step guide for students to follow during every STEM lesson procedure while providing real-life situations and problems to solve. It served as a beneficial teaching strategy because the process was consistent throughout each STEM lesson students performed.

Lesson self-reflections and teacher observations also served as documentation supporting the assertion that the Engineering Design Process through STEM provides a student-centered approach when teaching standard aligned content. A note I mentioned several times in my self-reflections was, “I like the process I have in place where I teach the content/vocabulary, dig into the process together as a class, and then let them design and build – making the learning process very student led rather than teacher led.” I found that by providing my students with a strong foundation of the content prior to the STEM lesson, the STEM lessons were much more successful and gave meaning and connection towards their learning. I had utilized various teaching strategies since the beginning of the year that were geared towards students learning the concepts independently via iPads or computers. The approach was student self-paced and I found that with my students’ various learning levels, it was difficult to assess whether they fully understood the concepts learned in this manner. I also noticed that many students had difficulty learning the concepts via technology and benefited from gaining the knowledge as a whole group where they could discuss their questions and answers as a class. Although my teaching approach was to be more student centered rather than teacher centered, I found that with my group of students, it was much more beneficial to instruct class as a whole to build a solid foundation of the science concepts and vocabulary I wanted them to understand. I then weaned away from leading the instruction to facilitating their learning through the STEM lesson that correlated with the lesson objective – changing the learning approach to more student-centered rather than teacher-centered.

In my teacher lesson reflections, I noted that the STEM lessons aligned with Nebraska State Standards, as well as NGSS Standards when the instructional objectives were to classify types of energies, convert energies, and evaluate the effect of the environment due to human use of natural resources as energy sources. I also documented that students' knowledge of the instructional objective was assessed using STEM learning post assessments, student STEM self-reflections, and an end of unit assessment. By open coding the teacher journal entries and lesson self-reflections, the selective code that emerged from the data was – Teaching standard aligned science concepts prior to STEM lessons, connecting real-life situations to STEM through the Engineering Design Process, and creating a student-centered learning environment are effective teaching strategies when implementing STEM in the upper elementary classroom.

Table 4

Open Codes, Axial Codes, and Selective Code for Teacher Journal Entries and lesson Self-Reflections

Open Code	Axial Code	Selective Code
Related knowledge deepens understanding of Science concepts prior to STEM lessons Teaching approach incorporating cooperation Use of science terms and concepts Assigning roles and asking question during STEM process Allotted time may need adjusting Make connection to real-life situations	Teaching strategies, such as teaching concepts prior to STEM, learning the concepts together as a class, and having students design and build through collaboration, as well as connecting through real-life situations, are effective in the upper elementary. Student-centered learning promotes success in STEM lessons.	Teaching standard aligned science concepts prior to STEM lessons, connecting real-life situations to STEM through the Engineering Design Process, and creating a student-centered learning environment are effective teaching strategies when implementing STEM in the upper elementary classroom.

Effective teaching approach based on sequence of teaching content, learning together as a class, then designing and building in groups.	
Student led rather than teacher led	
Engineering Design Process standard relates to STEM lessons	When the Engineering Design Process is embedded in STEM lessons, it can enhance student learning when aligned to standards.
STEM challenges aligned with standards	
Assessments reflect student learning	
Use of science terms and concepts	

Table 4 shows the axial codes and selective code based upon open codes. All other open codes, properties, and examples of teacher's words are displayed in the tables found in the appendices (see Appendix C).

Summary

The findings encompassing the research question – What happens to student engagement when students participate in NGSS aligned STEM lessons in a rural 4^{th} grade classroom? – led to the three assertions - STEM fosters student engagement in the upper elementary classroom, STEM enhances learning of science concepts in the upper elementary classroom and implementing the Engineering Design Process through STEM provides a student-centered approach when teaching standard aligned content. From the findings generated through analyzing the student interviews, the assertion that STEM fosters student engagement in the upper elementary classroom was determined. I found that students enjoyed learning science related content through STEM and that the learning of the content was easier to understand when their learning was supported through STEM lessons. Students felt they were more successful and engaged in the learning process when given the opportunity to learn with a hands-on approach where they could collaborate with their peers.

Learning of science concepts enhances student learning through integration of STEM was asserted by examining students' assessments and self-reflections, as well as teacher journal entries and self-reflections. The findings from the student assessments and reflections stipulate that integrating STEM lessons into a physical science unit to develop understanding of science content was beneficial to student learning and mastering of objectives. The findings that resulted through analyzing teacher journal entries and lesson self-reflections were that teaching science content and vocabulary prior to STEM lessons deepened students' knowledge of the concepts and gave more meaning to the lesson when students had previous background knowledge. The STEM lessons were used to improve the quality of student learning of lessons aligned to NGSS standards.

Effective teaching strategies, such as implementing the Engineering Design Process through STEM and student-centered learning were emphasized from open coding the teacher journal entries and lesson self-reflections. From my teacher journal entries and reflections, I noted students enjoyed real-world challenges that made their learning more concrete, which reflects a project-based learning approach to teaching. The open codes determined that students learning was enhanced when the teaching approach was more student-centered rather than teacher-centered. However, the findings did indicate that STEM lessons were more successful and beneficial to student learning when the science content was thoroughly taught and explained to the whole class by the teacher, which is a more teacher-led approach. Once the background knowledge and concepts were mastered, students applied the Engineering Design Process to design, create, build, and collaborate with their peers, changing the teacher strategy to a more student-centered approach rather than teacher-centered. Students also were more engaged and motivated to persevere through the STEM lesson when given real-life situations and problems to solve.

CHAPTER 5: DISCUSSION AND CONCLUSIONS

Overview

Data were collected and analyzed to support the action research surrounding the question - What happens to student engagement when students participate in NGSS aligned STEM lessons in a rural 4th grade classroom? From this data, I referred back to the literature review to discuss and interpret the findings and made connections to prior research. I then discussed the takeaways from this study and any recommendations that can be made for other teachers, as well as for my own practice. The limitations on the topic of this qualitative study are discussed and can provide indications for the need of future research.

Discussion

The research project conducted provided insight on how student's perceive STEM, as well as the various ways STEM can influence students' learning process. The research also discussed effective teaching strategies that affect student learning in STEM, as well as align to NGSS standards. This research action proposed the three assertions: 1) STEM fosters student engagement in the upper elementary classroom 2) STEM enhances learning of science concepts in the upper elementary classroom 3) Implementing the Engineering Design Process through STEM provides a student-centered approach when teaching standard aligned content.

Hall and Miro (2016) note that engaging students in STEM by focusing on real-world issues and problems is essential in stimulating students towards STEM workforce careers. In the qualitative study conducted by Hall and Miro (2016) applying a Project Based Learning (PBL) framework in classrooms has been found to increase STEM learning. Just like Hall and Miro (2016), my research also found student participation in learning approaches, such as Project-Based Learning, engages students in STEM by providing them with opportunities to solve problems to questions based on real-life situations, use ingenuity to discover solutions to problems, and collaboratively work together to find a common resolution. I found that centering my STEM lessons around real-world situations and challenges engaged my students and made a deeper connection to their learning. Project-based learning also emphasizes hands-on learning that promotes a student-centered learning environment. My research also suggests that teacher-centered learning prior to STEM lessons deepens students' understanding of the content. However, when students apply their understanding of content through the STEM lesson, the focus shifts towards a student-centered learning environment. Although Hall and Miro's study took place in four secondary STEM education settings, whereas my research was conducted in an upper elementary science classroom focusing on a solitary grade level, the similarities of findings suggests this may be a universal theme for students across different settings.

When provided effective teaching strategies and approaches, STEM enhances learning of science concepts in the upper elementary classroom. Roberts and Cantu (2012) discuss the *integrated* approach and how it allows students to apply knowledge to different content areas and combine skills from various STEM fields. Like Roberts and Cantu (2012), I utilized the *integrated* approach to impact student learning of science content. Although the focus of my research took place in a science classroom and STEM was used to strengthen understanding of science concepts, students used the integrated STEM approach where other academic areas supported the mastery of science content.

Integrating science, technology, engineering, and mathematics unified these subjects so that students could develop their understanding of science-related concepts.

By focusing the content of my science lessons on the NGSS standards and the Engineering Design component, my study promotes the integration of STEM lessons to enhance the learning of these standards. Similar to the study conducted by Guzey, Moore, and Harwell (2016), the STEM lessons performed in my research were also focused on students engaging in real-world related problems where they were asked to design, build, test, and re-design. The research conducted in my classroom, however, was over a six-week period centered around one science unit, whereas the study performed by Guzey, Moore, and Harwell (2016) provided a year-long teacher professional development program where teachers developed their own STEM units and tested these units through implementation throughout the year. Although the time frames of each study are different in comparison, the findings propose similarities that focus around the integration of the Engineering Design Process in STEM lessons. Like Daily (2017), my research also extends to show that implementing the Engineering Design Process through STEM will provide a student-centered approach while still teaching standard aligned content.

Conclusions

The research performed in the 4th grade classroom during the spring of 2019 will provide myself with knowledge on implementation of STEM in the elementary and will extend into my 3rd and 5th grade science classes. From this experience, I plan to continue emphasizing the Engineering Design Process within my STEM lessons by dedicating one day per week to a specific engineering curriculum provided through the Engineering is Elementary website (eie.org) that develops student knowledge on engineering fields and concepts while applying science and math skills. Utilizing this curriculum will improve my students' knowledge on what engineers essentially do. It will also integrate all STEM components while providing students the ability to work with a more hands-on approach where the learning is centered around the student – a teaching strategy I found to be effective during my research study.

I also plan to improve the use of technology within my classroom by incorporating more technical devices that will support our local science curriculum. The technology teacher and I have been in contact with each other and have planned various ways we can integrate more technology into the elementary classrooms. Technology is not something that is abundant in our school district, but with grant opportunities, I'm hopeful that will change. If grants are awarded, technology will be utilized through the introduction to coding in the elementary grades through a coding and robotics after-school program. Due to the demographics of our school district, many of our students do not have access to technology within their homes. By exposing our elementary students to different forms of technology, we will better prepare them for high school and college courses, as well as a plethora of careers in the workforce.

Not only is it essential that I continue implementing STEM in the classroom and continue growing as an educator in the field of STEM, but I also feel that other teachers within my school district must be aware of the importance of STEM as well. As previously stated, I have communicated the importance of incorporating more technology into the elementary classrooms with our technology teacher through a potential coding and robotics after-school program. My administration also is interested in providing professional development time where I can discuss implementing STEM in the lower elementary grades and serve as a STEM mentor to other elementary teachers. I also plan to extend my knowledge to other teachers in the state of Nebraska by presenting ideas and lessons at the Nebraska Association of Teacher of Mathematics and Nebraska Association of Teachers of Science (NATM/NATS) Conference that is held every September in Kearney, Nebraska.

Limitations

As a qualitative study, the research completed cannot be generalized to all upper elementary classrooms. Since data was collected in a rural school district with small class sizes, the sample size was small, therefore, it would be difficult to find significant relationships and valid conclusions from the data. The self-reported data acquired during this research may be noted as a source of bias and should be noted as a limitation to the study.

Future Research

To further support and expand on the findings of my research action, future research still needs to be conducted on the topic of effective instructional strategies that support STEM in the upper elementary classroom. The limitations of this study support the need for further research as the small sample size and self-reported data are too generalized. It is also important to note that because the research was conducted over a six-week period, a longer duration could have differing results. Since this action research focused on STEM engagement and science concepts, further research may need to address the topic of effective instructional strategies that support STEM engagement in upper elementary classrooms with an emphasis on math or technology concepts.

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APPENDIX A: Student Interview Questions

1. Why do you find it important to participate in STEM lessons?
2. STEM stands for integrating Science, Technology, Engineering, and Mathematics. Which part of STEM do you find the most important and why?
3. STEM lessons require students to work collaboratively together. How do you work with others to solve problems?
4. How has your attitude towards Science changed since completing STEM lessons this year?
5. What would you tell someone who is new to our class what it takes to be successful during STEM lessons?
6. How does your level of understanding of STEM related subjects change when participating in STEM lessons?
7. What happens to your level of engagement during class when you participate in STEM lessons?
8. How has your willingness to persist through a problem changed since participating in STEM lessons?
9. Part of the Engineering Design Process is redesigning to make your prototype better.
10. This semester I have changed some of my teaching practices by adding more STEM lessons into our Science content. What advice would you give me about continuing these changes next year?

APPENDIX B: Grounded Theory Approach – Student Interviews

Interview Question #1: Why do you find it important to participate in STEM lessons?

Open codes for Q1

Open Code	Properties	Examples of Student's Words
Hands on learning/physical movement	Seeking movement Kinesthetic Artistic Ingenuity	Physical activity makes me remember what I learned Fun Gives a challenge and makes your brain work Makes your creativity go free
Enhanced Learning of concepts	Better understanding of academic concepts	Learning what the teacher's teaching (2) Remember what I learned better I get better grades when I participate in STEM

Interview Question #2: STEM stands for integrating Science, Technology, Engineering, and Mathematics. Which part of STEM do you find the most important and why?

Open codes for Q2

Open Code	Properties	Examples of Student's Words
Science and math are key components in STEM	Combining subject areas Science Technology Engineering Mathematics	All of them Mathematics because I like the math part Science because it helps me with science Math and science because you need to have mathematics to make machines work correctly

Interview Question #3: STEM lessons require students to work collaboratively together. How do you work with others to solve problems?

Open Codes for Q3

Open Code	**Properties**	**Examples of Student's Words**
Wanting peer interaction for teamwork skills	Collaboration Working as a team	If you have many ideas, you can put them together instead of just doing your idea Working together Being creative together We all pitch in
Combining peer ideas	Discussing ideas	Bounce ideas off people to get better ideas We get an idea and combine it together If you have many ideas, you can put them together instead of just doing your idea

Interview Question #4: What would you tell someone who is new to our class what it takes to be successful during STEM lessons?

Open Codes for Q4

Open Code	**Properties**	**Examples of Student's Words**
Being a team player	Working as a team	Working together Being creative Working collaboratively with people Working together as a team
Don't fear failure	Don't give up Keep trying	Don't flip out if something doesn't work the first time Try it again If it doesn't work, try, try, try again

Interview Question #5: How does your level of understanding STEM related subjects change when participating in STEM lessons?

Open Codes for Q5

Open Code	Properties	Examples of Student's Words
Learning of content is easier to grasp	Makes learning easier and more understandable	Easier way to understand material I understand the material better I understand science concepts better I understand them I don't like someone straight telling me something, I like the examples STEM gives you

Interview Question #6: What happens to your level of engagement during class when you participate in STEM lessons?

Open Codes for Q6

Open Code	Properties	Examples of Student's Words
Participating in STEM keeps me engaged and excited to learn.	Excited to learn Involved through hands-on learning	It increases because I love STEM I am more engaged because I use my ideas It makes me more involved with hands-on learning I get excited

Interview Question #7: How has your willingness to persist through a problem changed since participating in STEM lessons?

Open Codes for Q7

Open Code	**Properties**	**Examples of Student's Words**
Persisting through work is easier to do now than it was at the beginning of the year.	Persist through challenges	I'm not upset because at least I tried I can always redo it to make it better I can work through things better now I work harder to work through problems I gave up at the beginning of the year, but I am getting better at not giving up.

Interview Question #8: Part of the Engineering Design Process is redesigning to make your prototype better. What has happened when you have had to redesign your prototype?

Open Codes for Q8

Open Code	**Properties**	**Examples of Student's Words**
Redesign is beneficial in making my project work more effectively.	Redesigning is beneficial	Making it better will equal out the errors Makes my project work better Always gets better

Interview Question #9: This semester I have changed some of my teaching practices by adding more STEM lessons into our Science content. What advice would you give me about continuing these changes next year?

Open Codes for Q9

Open Code	Properties	Examples of Student's Words
I should continue STEM lessons next year because hands on learning helps students understand concepts.	Continue STEM lessons STEM lessons help students better understand material	I think you should continue STEM lessons because hands on learning is better for kids than paper You should do it I like the way you are doing things I think you should continue because it will help students understand force, potential, and kinetic energy

Axial codes and selective code based on the open codes

Open Code	Axial Code	Selective Code
I should continue STEM lessons next year because hands on learning helps students understand concepts; learning of content is easier to grasp; hands on learning/physical movement; enhanced learning of concepts; participating in STEM keeps me engaged and excited to learn.	Participating in hands on learning through STEM lessons excites and helps students understand concepts easier.	STEM lessons challenge, excite, and help students better understand concepts through student collaboration.
Redesign is beneficial in making my project work effectively; persisting through work is easier now than at the beginning of the year; don't fear failure.	STEM helps students work through challenges.	

Be a team player; wanting peer interaction for teamwork skills; combining ideas	Collaboration of ideas helps in STEM lessons.	
Science and Math are key components in STEM	Engineering and Technology are overlooked in STEM.	

APPENDIX C: Grounded Theory Approach – Teacher Journal Entries and Lesson Self-Reflections

Teacher Journal Entries

Open Code	**Properties**	**Examples of Teacher's Words**
Related knowledge deepens understanding of Science concepts prior to STEM lessons	Providing background knowledge Correlates with standards Science concepts are addressed before and during STEM lesson	Addressing lessons to standards Taught vocab and content prior to lesson Deep understanding of concept before STEM lesson Science vocab/concept connections Gain deeper understanding of energy in motion Provide background knowledge of concept Reading and background information on solar energy prior to lesson

Open Code	**Properties**	**Examples of Teacher's Words**
Engineering Design Process standard relates to STEM lessons	Standards address Engineering Design Process STEM lessons correlate with Engineering Design Process	Engineering Design Process Create and design Standard SC4.4.2.D – design, test, refine a device that converts energy from one form to another Design and create solar vehicle Engineering Design Process Tasks before designing Incorporates Engineering Design Process Answering questions to enhance design Research Design and label

Open Code	Properties	Examples of Teacher's Words
Teaching approach incorporating cooperation	Collaboration Participation	Engaged, collaborative groups Engagement supplemental piece to introduce concept Engaged, excited students Work in groups Each group member's ideas

Teacher Lesson Self-Reflections

Reflection Question #1: Was the instructional objective met? How do I know students learned what was intended?

Open Codes for Q1

Open Code	Properties	Examples of Teacher's Words
STEM challenges aligned with standards Assessments reflect student learning	Standards were addressed through STEM challenges Assessments were created Students participated in self-reflections	STEM challenges supported Nebraska State Standards Classify types of energies, convert energies, evaluate the effect of the environment due to human use of natural resources as energy sources STEM Learning Assessment used as post assessment Students will complete post self-reflections

Reflection Question #2: Were the students productively engaged? How do I know?

Open Codes for Q2

Open Code	Properties	Examples of Teacher's Words
Use of science terms and concepts were used appropriately Assigning roles and asking question during STEM process	Use of terms were used Role assignment Engaging in question Relating concepts to STEM lesson Utilizing time efficiently	Actively take part Asking each other questions Assigning each other tasks Verbalizing science vocabulary through STEM design/building process Noticed the energy transfer Used allotted amount of time

Reflection Question #3: Did I alter my instructional plan as I taught the lesson? Why?

Open Codes for Q3

Open Code	Properties	Examples of Teacher's Words
Allotted time may need adjusting Make connection to real-life situations	Time constraints Instruction centered around real-life situations	Design, test, and redesign took longer than anticipated No alterations – connecting information to real world situations

Reflection Question #5: If I had the opportunity to teach the lesson again to the same group of students, would I do anything differently? What? Why?

Open Codes for Q5

Open Code	Properties	Examples of Teacher's Words
Setting constraints and conversing with groups will impact fluidity of lesson	Time constraints Converse with groups on planning guides prior to designing	I would have looked at planning guides/designs of the students before letting them design Set up time constraints

Effective teaching approach based on sequence of teaching content, learning together as a class, then designing and building in groups. Student led rather than teacher led	Keep teaching process in place for effective teaching	I have a positive process in place - teaching content/vocab, digging into the process together as a class, and then let them design and build makes the learning process student led rather than teacher led.

Axial codes and selective code based on the open codes

Open Code	**Axial Code**	**Selective Code**
Related knowledge deepens understanding of Science concepts prior to STEM lessons Teaching approach incorporating cooperation Use of science terms and concepts Assigning roles and asking question during STEM process Allotted time may need adjusting Make connection to real-life situations Effective teaching approach based on sequence of teaching content, learning together as a class, then designing and building in groups. Student led rather than teacher led	Teaching strategies, such as teaching concepts prior to STEM, learning the concepts together as a class, and having students design and build through collaboration, as well as connecting through real-life situations, are effective in the upper elementary. Student-centered learning promotes success in STEM lessons.	Teaching standard aligned science concepts prior to STEM lessons, connecting real-life situations to STEM through the Engineering Design Process, and creating a student-centered learning environment are effective teaching strategies when implementing STEM in the upper elementary classroom.
Engineering Design Process standard relates to STEM lessons STEM challenges aligned with standards Assessments reflect student learning Use of science terms and concepts	When the Engineering Design Process is embedded in STEM lessons, it can enhance student learning when aligned to standards.	